Virtual Asian IBIS Summit (China), November 19, 2021

An Efficient Analysis Method for IBIS Eye-diagram Edge Analysis Based on PDA

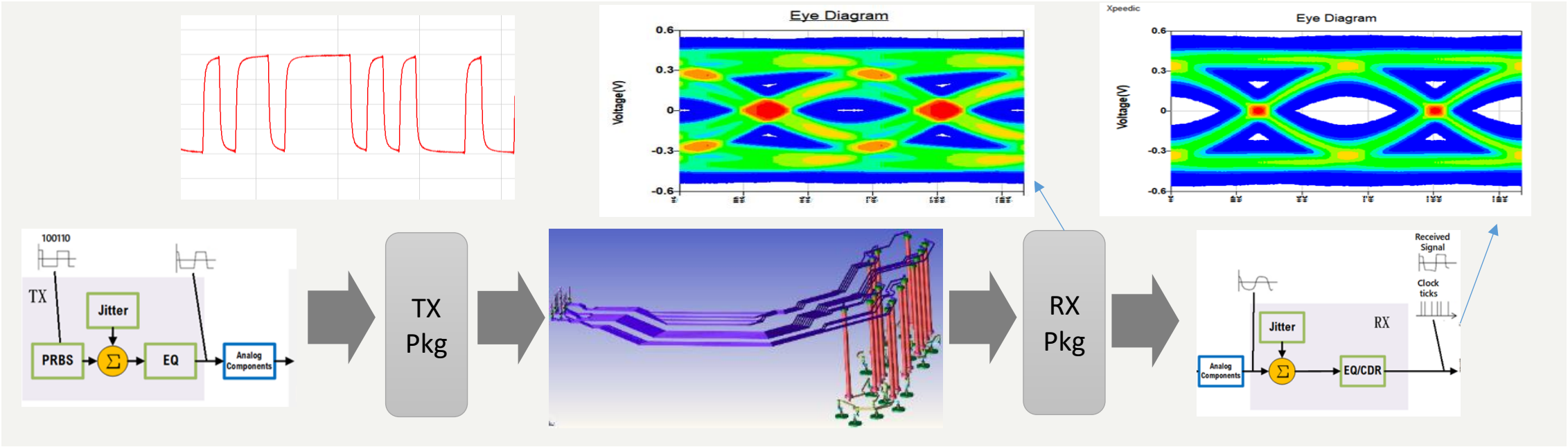
Wei He , Jianfeng Xia , Yufeng Dan , Chengzhi Hu
Xpeedic Co., Ltd.

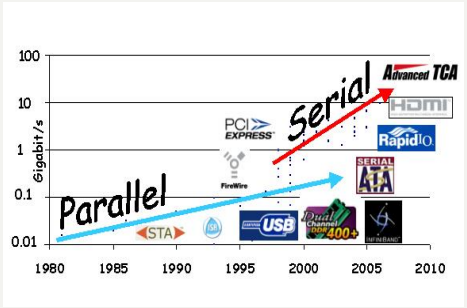
XPEEDIC
ACCELERATE YOUR IC DESIGN

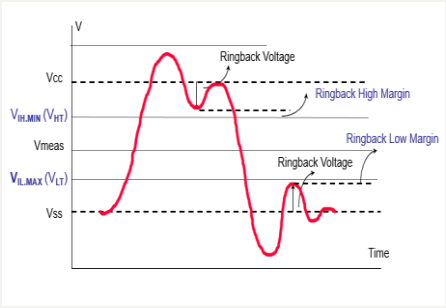
Outline

- Background: Challenges in Eye-diagram Analysis of High-speed Systems
- Simulation technique (Bit-by-bit, Statistical)
- I: Peak Distortion Analysis
- II: Peak Distortion Analysis Work Flow
- III: Simulation Result Comparisons
- Summary

Challenges in Eye-diagram Analysis of High-speed Systems



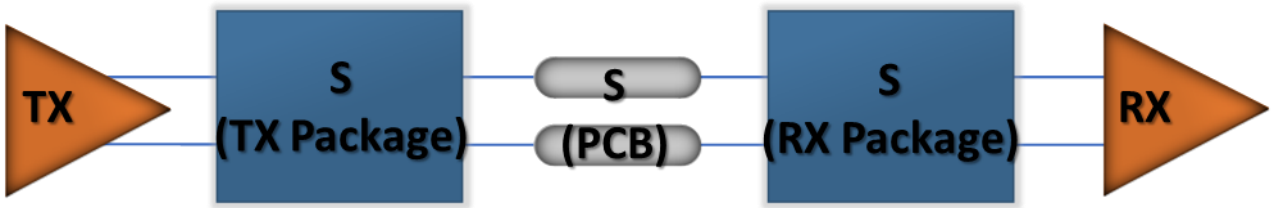




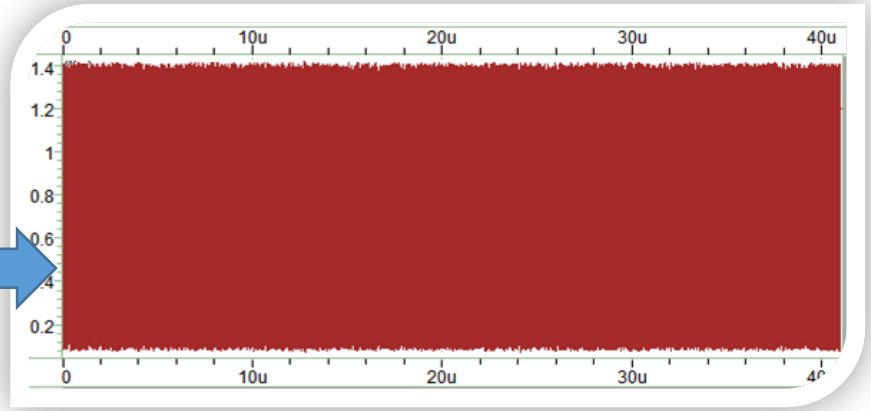
- Signal Rate
- Return Loss
- ISI
- Jitter
- Crosstalk
- Noise

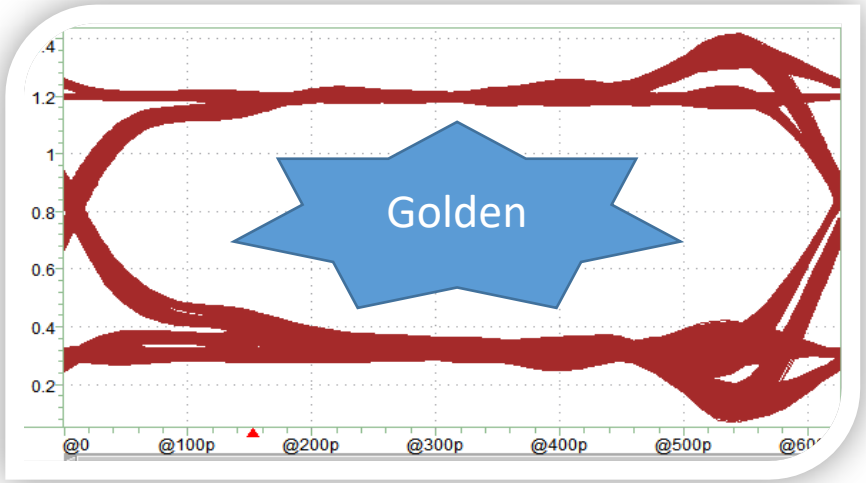
- ✓ Lossy coupled transmission lines
  - –Inter-Symbol Interference (ISI) and Crosstalk co-exist
- ✓ Highly nonlinear transistor buffer
  - –Tens of thousands of transistors
  - –Simultaneous Switching Operation (SSO) strongly affects driver timing
- ✓ Low BER requirement for (LP)DDR4
- ✓ Equalizer (FFE and/or DFE) requirement for DDR5

Simulation technique - Bit-by-bit



PRBS16
65536个bits





- Captures any non-LTI effects
- ISI and crosstalk effect can accurately be taken
- Depend on more bits for accuracy
- Time consuming
- Difficult to establish multistage flow
- Difficult to take Tx-AMI model if non-LTI
- Non-LTI Rx-AMI can be taken

Simulation technique - Statistical

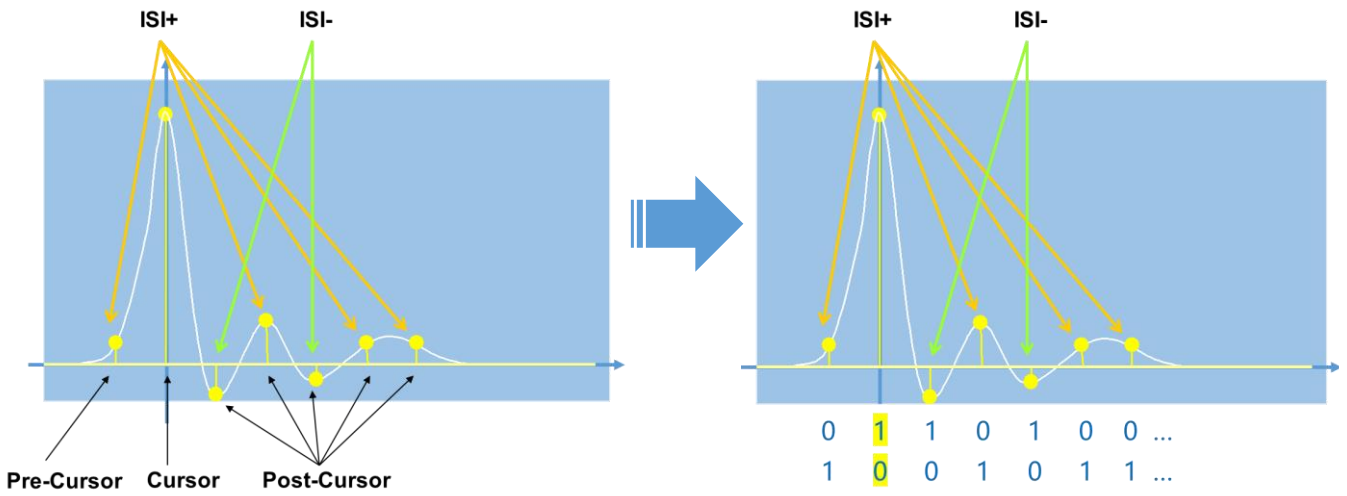
- Compared to the traditional bit-by-bit, statistical eye can get a lower error rate, when the simulation bit number tends to infinity, the two simulation modes are equivalent, but the statistical eye is faster, because it only needs one bit to count.
- Steps of statistical eye simulation .
  - Calculate the SBR (Single-Bit-Response)
  - Get the Cursor Domain
  - Count the PDF
  - Calculate the CDF and BER
  - Eye measurement
  - Display the Eye

Peak Distortion Analysis

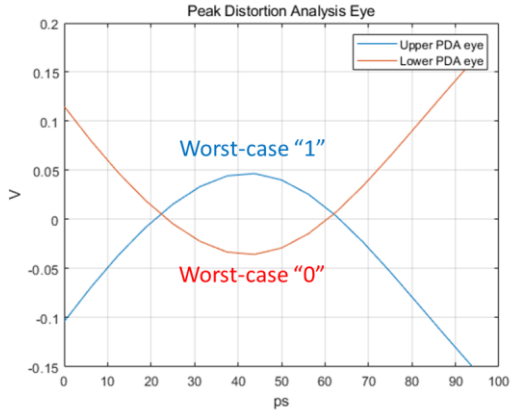
- Peak distortion analysis (PDA) calculates the worst case bit pattern from the step responses of the channel for eye analyses. Peak distortion analysis is calculated for each combination of Eye Source and Eye Probe.
- Can estimate worst-case eye height and data pattern from pulse response
- Worst-case “1” is summation of a “1” pulse with all negative non k=0 pulse responses
- Worst-case “0” is summation of a “0” pulse with all positive non k=0 pulse responses

Theoretical: Peak Distortion Analysis

- SBR based PDA



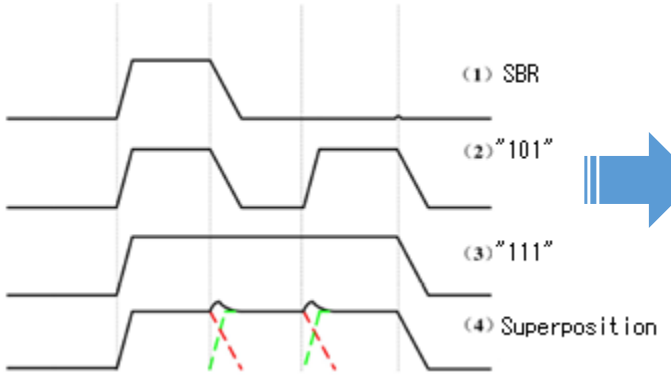
Worst Case



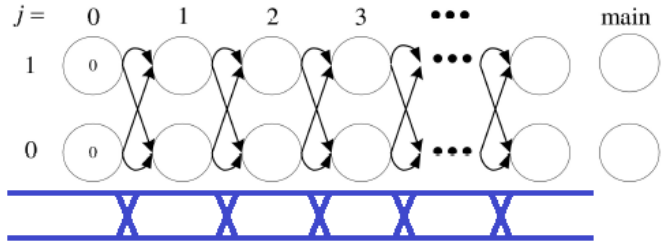
$$S_1(t) = y(t) + \sum_{\substack{k=-\infty \\ k\neq 0}}^{\infty} y(t-KT)\big|_{y(t-KT)<v_{ss0}}$$

$$S_0(t) = \sum_{\substack{k=-\infty \\ k\neq 0}}^{\infty} y(t-KT)\big|_{y(t-KT)>v_{ss0}}$$

- DER based PDA



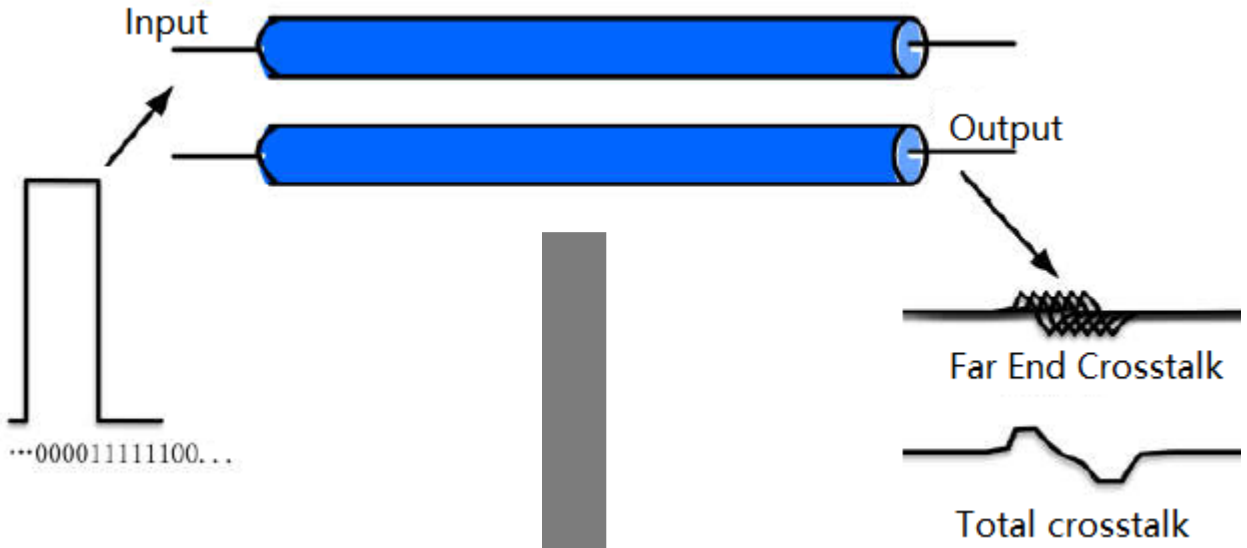
Worst Case



$$y(t) = \left[\sum_{k=-\infty}^{\infty} (d[kT] - d[kT-T]) \cdot u(t-kT)\right] \otimes h(t)$$

$$= \sum_{k=-\infty}^{\infty} [(d[kT] - d[kT-T]) \cdot s(t-kT)]$$

Theoretical: Peak Distortion Analysis

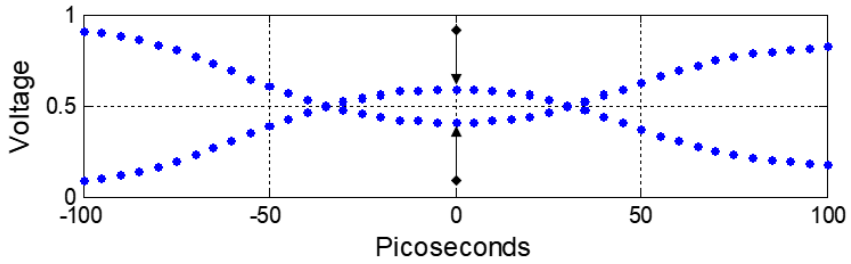


Worst-case “1”

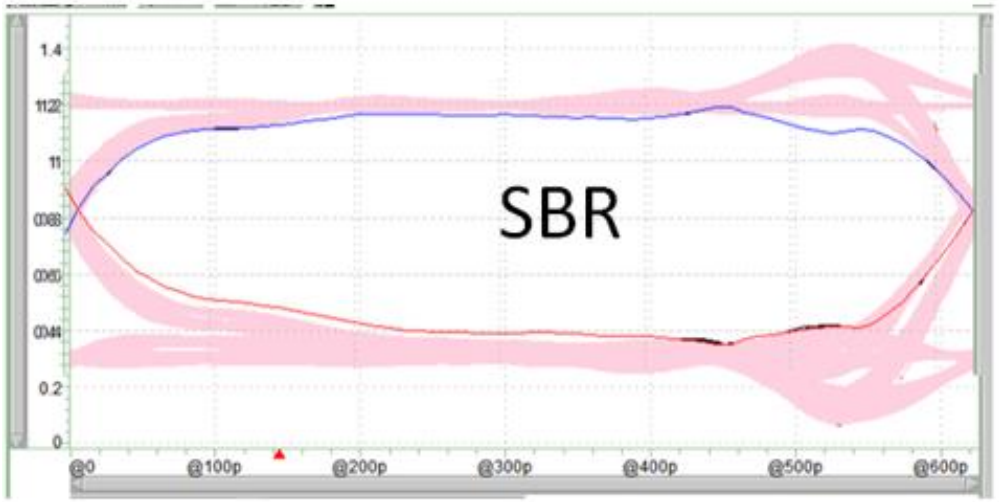
Worst-case “0”

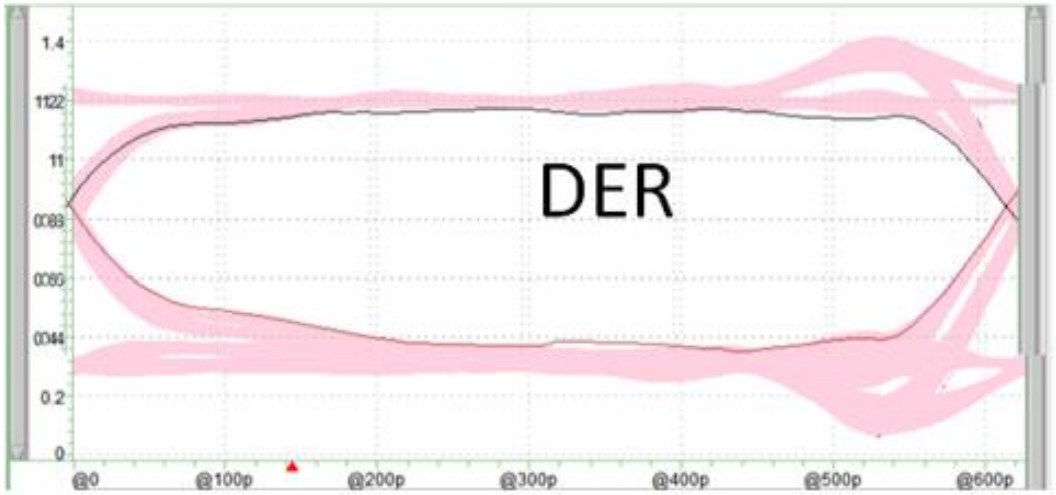
$$S_1(t) = y(t) + \sum_{\substack{k=-\infty \\ k\neq 0}}^{\infty} y(t-KT)\big|_{y(t-KT)<v_{s0}} + \sum_{i=1}^{n}\sum_{k=-\infty}^{\infty} y^i(t-KT-t_i)\big|_{y^i(t-KT-t_i)<v_{s0}}$$

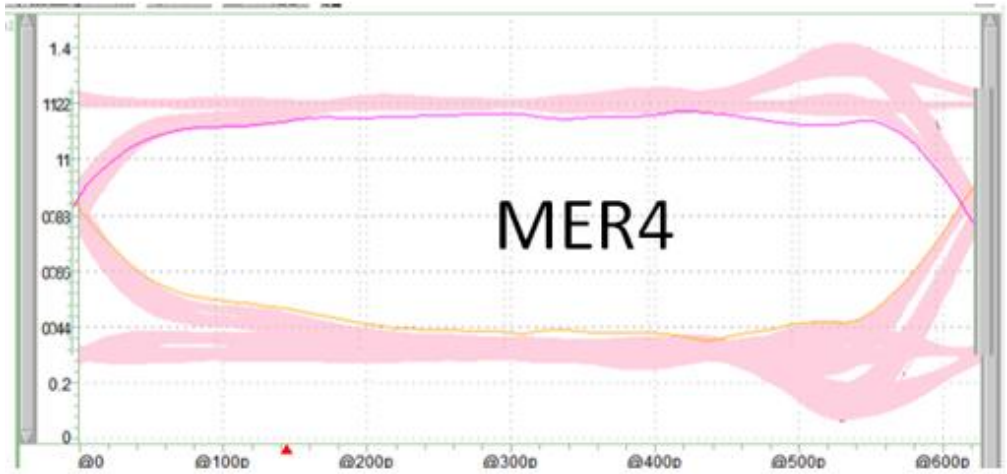
$$S_0(t) = \sum_{\substack{k=-\infty \\ k\neq 0}}^{\infty} y(t-KT)\big|_{y(t-KT)>v_{s0}} + \sum_{i=1}^{n}\sum_{k=-\infty}^{\infty} y^i(t-KT-t_i)\big|_{y^i(t-KT-t_i)>v_{s0}}$$

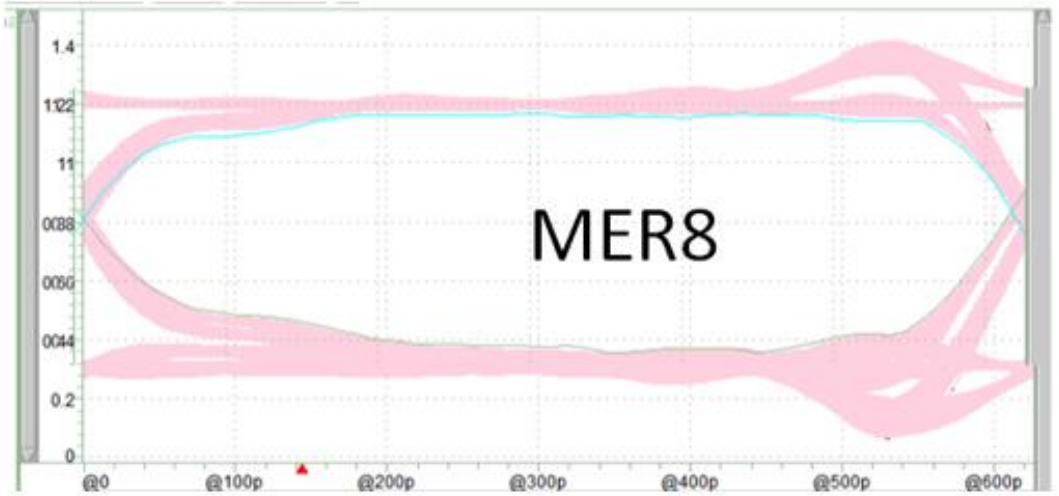


PDA method Result Comparison



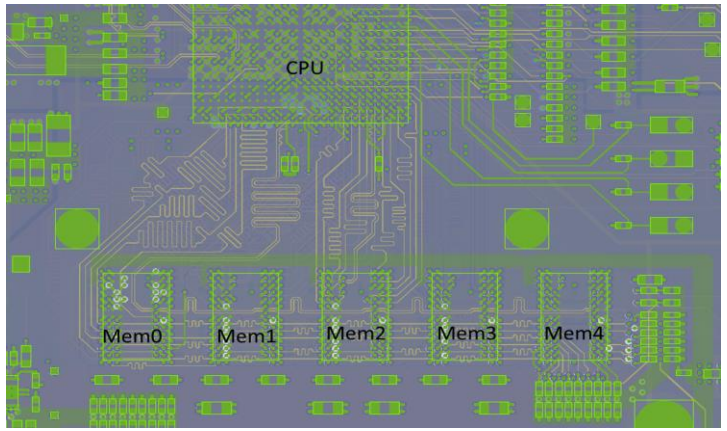


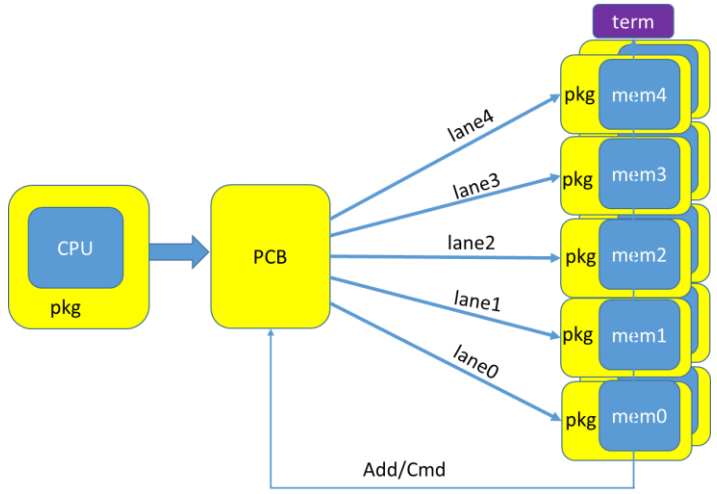


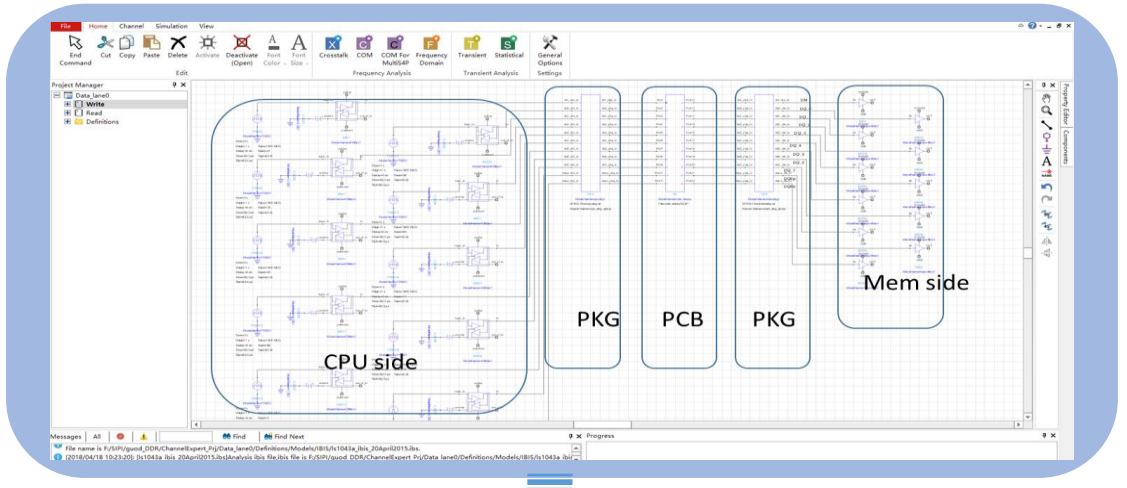


Peak Distortion Analysis Work Flow

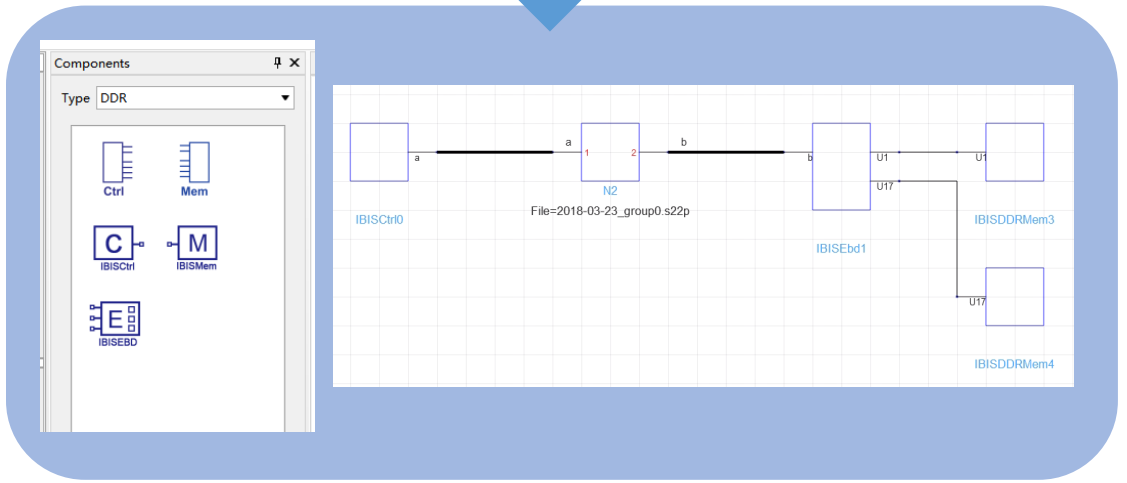
Schematic topology → Buffer selection → data rate settings → Choose simulation method → Run



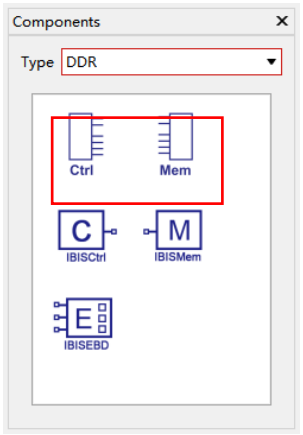


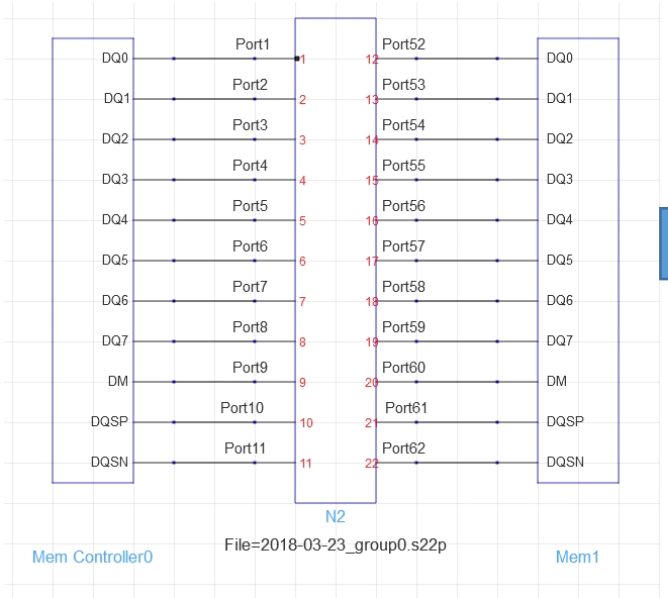


DDR BUS



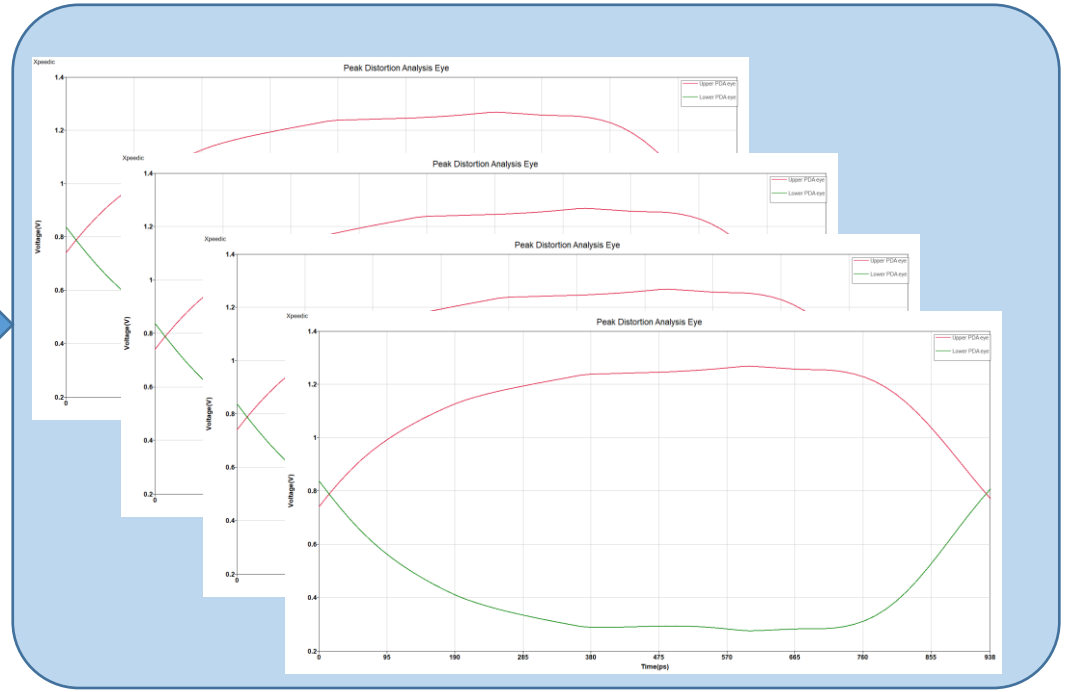
Built in 8bit data bus

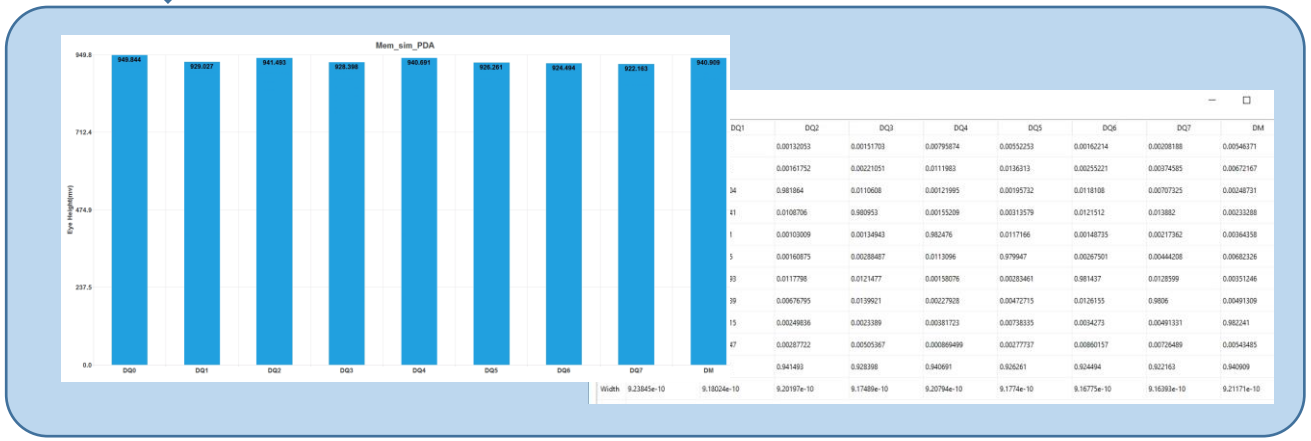




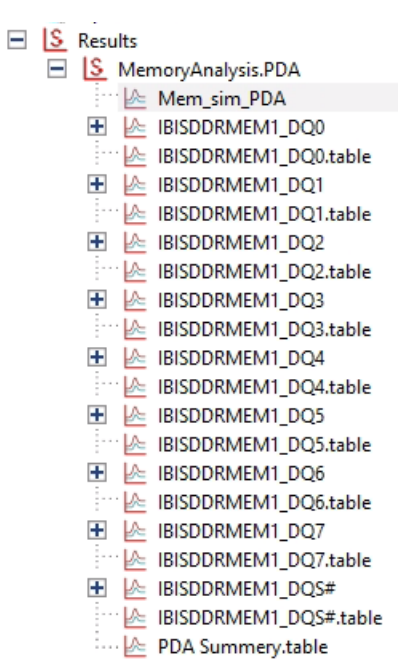
Eye inner contour

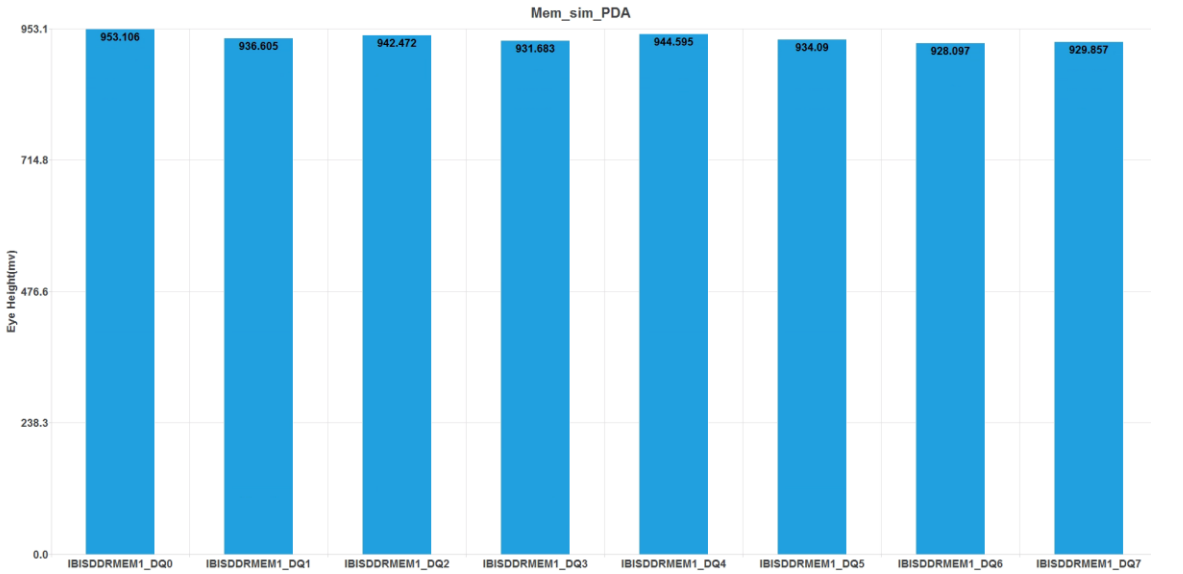
summary





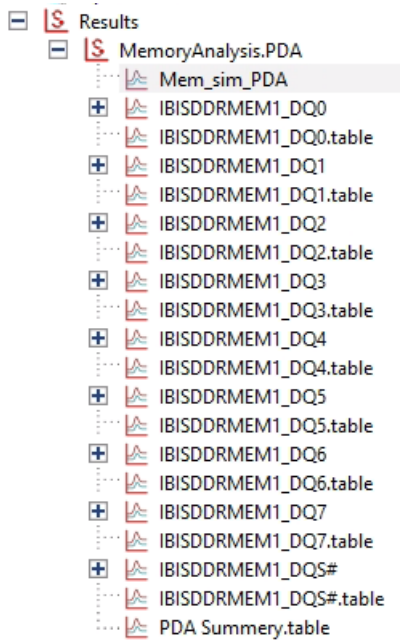
CPU→MEM (PDA SBR) – Results1



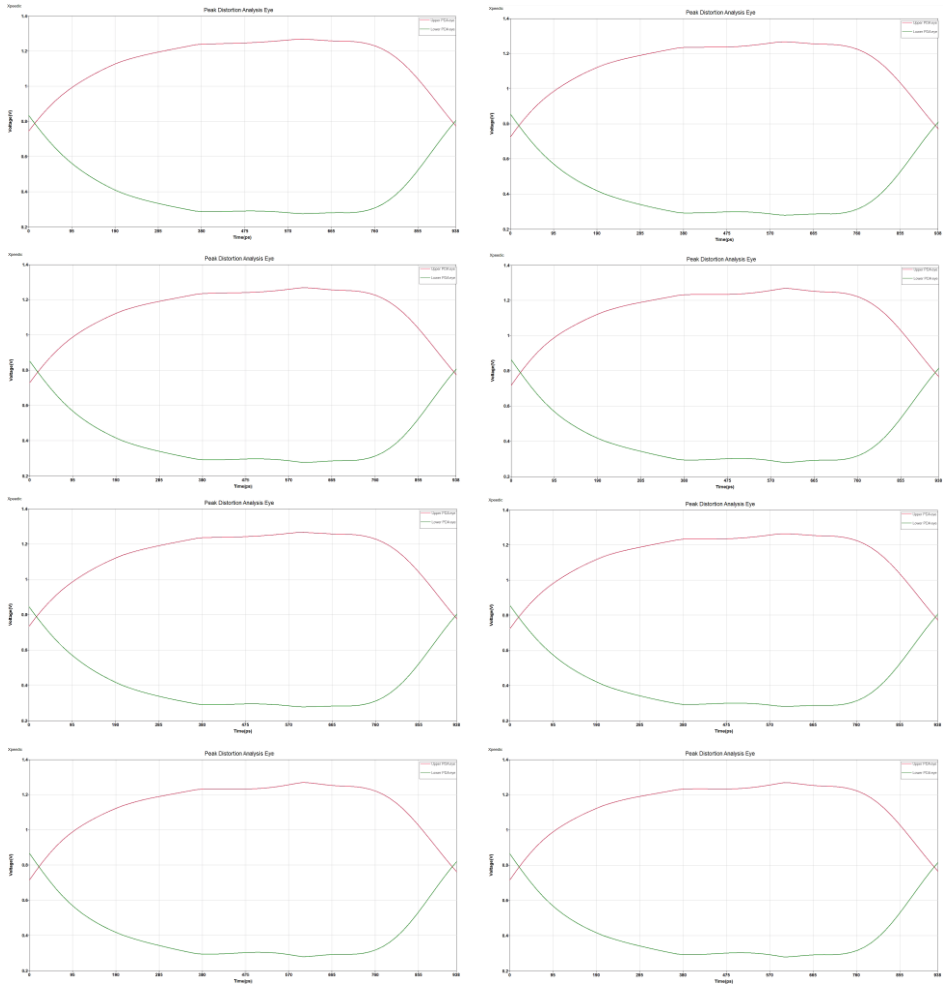


	IBISDDRMEM1_DQ0	IBISDDRMEM1_DQ1	IBISDDRMEM1_DQ2	IBISDDRMEM1_DQ3	IBISDDRMEM1_DQ4	IBISDDRMEM1_DQ5	IBISDDRMEM1_DQ6	IBISDDRMEM1_DQ7
IBISDDRMEM1_DQ0	0.984427	0.00993561	0.00137744	0.00159565	0.00797852	0.00556119	0.00170545	0.00216656
IBISDDRMEM1_DQ1	0.00979183	0.982225	0.00169002	0.00226488	0.0112409	0.0136884	0.00265373	0.00384467
IBISDDRMEM1_DQ2	0.00126927	0.00171117	0.981844	0.0111876	0.00127198	0.00202117	0.0119377	0.00720631
IBISDDRMEM1_DQ3	0.00139874	0.00228923	0.0109862	0.98092	0.0016087	0.0032092	0.0123047	0.0140058
IBISDDRMEM1_DQ4	0.00775775	0.0111342	0.00106216	0.00137473	0.982468	0.0117499	0.001526	0.00222412
IBISDDRMEM1_DQ5	0.00533964	0.013011	0.00165347	0.00292696	0.011345	0.979924	0.00272605	0.00452187
IBISDDRMEM1_DQ6	0.0016038	0.0026749	0.0119012	0.0123107	0.00164784	0.0029188	0.981369	0.0130345
IBISDDRMEM1_DQ7	0.00207614	0.0038335	0.00689687	0.0140782	0.00234025	0.00480934	0.0127846	0.980528
DQS	0.00208334	0.00102983	0.00380473	0.00349886	0.000439853	0.00187617	0.00763397	0.00366752
Height	0.953106	0.936605	0.942472	0.931683	0.944595	0.93409	0.928097	0.929857
Width	9.24768e-10	9.19475e-10	9.20124e-10	9.17728e-10	9.21573e-10	9.1906e-10	9.16984e-10	9.17264e-10

CPU→MEM (PDA SBR) – Results2



Eye inner contour of each data



CPU→MEM (PDA DER) – Results

mem_sim_PDA

PDA Tran

Excitations DER

ISI threshold 0.1 mV

Eye resolution 0.1 mV

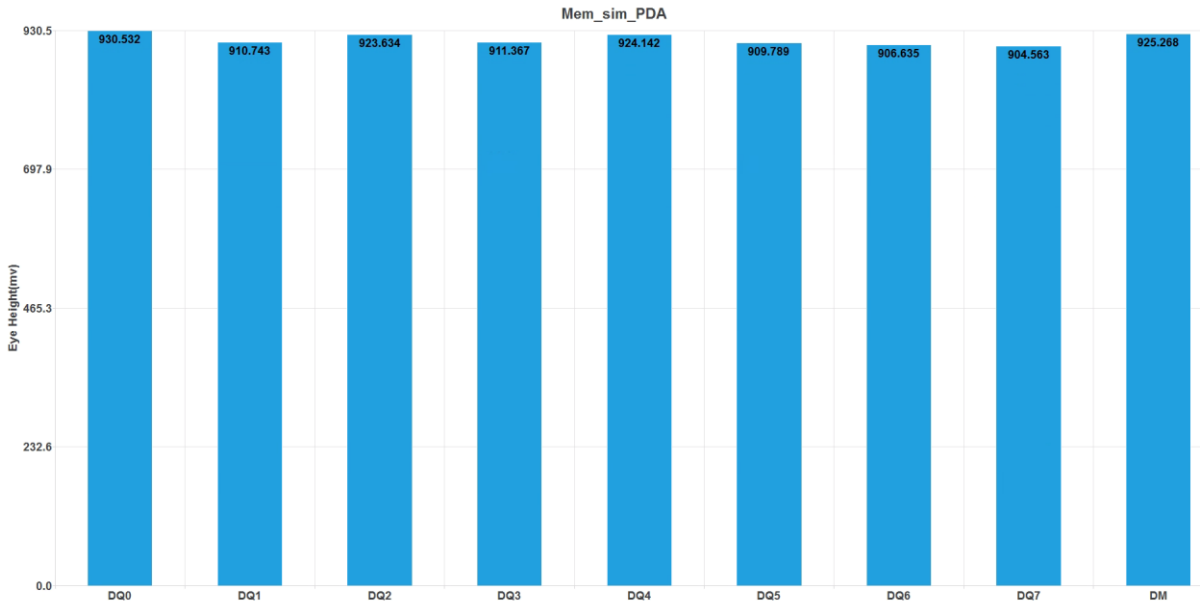
64 pts/UI

Advanced Settings

Analog channel response estimation

Step: 0.01 UI

Stop: 20 UI

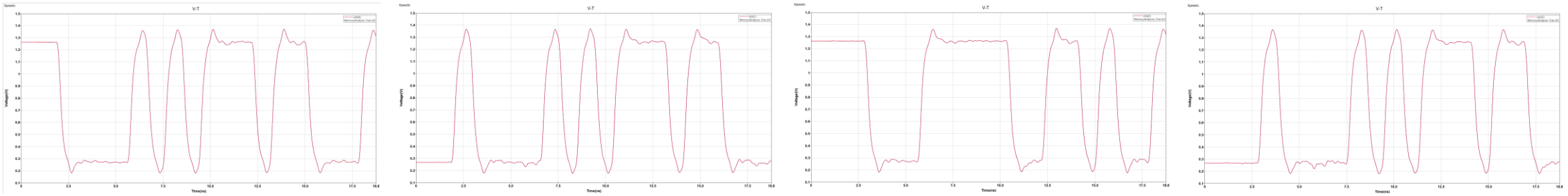


PDA Summary

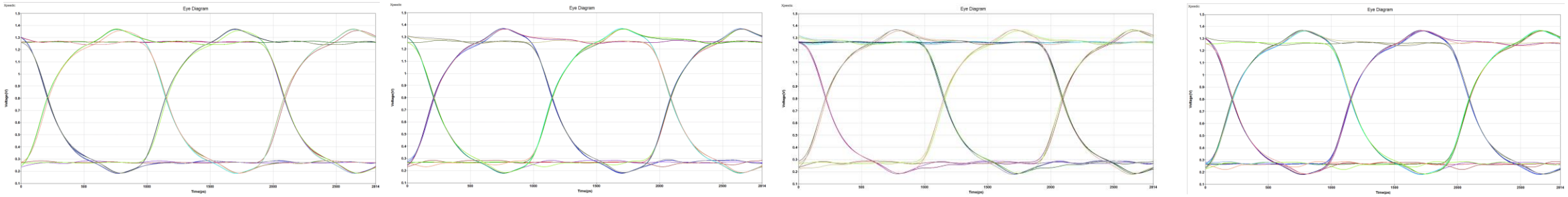
	DQ0	DQ1	DQ2	DQ3	DQ4	DQ5	DQ6	DQ7	DM
DQ0	0.970256	0.0109305	0.00170352	0.00196688	0.00887698	0.00600861	0.00216514	0.00260843	6.1091e+09
DQ1	0.0108275	0.970812	0.00222467	0.0027954	0.012557	0.0150216	0.00338185	0.00449878	7.38906e+09
DQ2	0.00163729	0.00223864	0.96948	0.0121966	0.00157872	0.00252989	0.0132627	0.00817248	2.87506e+09
DQ3	0.00184182	0.00288389	0.0119804	0.970175	0.00198267	0.00366074	0.0136237	0.0157809	2.8992e+09
DQ4	0.00866136	0.0125448	0.00142157	0.00174779	0.97108	0.0125789	0.0019728	0.00268712	4.0648e+09
DQ5	0.00592655	0.0144179	0.00212813	0.00338782	0.0121891	0.968713	0.00328265	0.00493349	7.27412e+09
DQ6	0.00209747	0.00339463	0.0132908	0.0136361	0.0021345	0.00361916	0.969882	0.0143775	4.11369e+09
DQ7	0.00254064	0.0044252	0.0079995	0.0158947	0.00279036	0.005401	0.0143074	0.969105	5.45343e+09
DM	0.00600948	0.00733908	0.00294679	0.00301408	0.00421094	0.00805727	0.00416951	0.00559136	9.69587e+11
DQS	0.000181671	0.00189459	0.00215044	0.0041688	0.000618322	0.00204693	0.00708119	0.0058919	4.14018e+09
Height(V)	0.930532	0.910743	0.923634	0.911367	0.924142	0.909789	0.906635	0.904563	9.25268e+11
Width(ps)	934.529	929.023	931.045	928.872	931.66	928.785	928.428	927.826	932.343

CPU→MEM (transient) – Results

V-T waveform



Eye-diagram



Summary

- PDA (Peak Distortion Analysis) analysis, quickly calculates the inner contour of channel eye diagram through the unit impulse response, and gives the influence of ISI and xtalk sources on eye diagram margin
- SBR is a fast and efficient way to signal edges that are symmetrical
- DBR is a more accurate way to asymmetrical signal edges
- For asymmetric signal edges and nonlinear channels, the performance of the channel can only be accurately evaluated using the MER method


XPEEDIC
ACCELERATE YOUR IC DESIGN